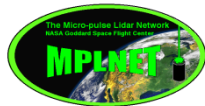


New MPLNET PBL Algorithm Reveals Previously Undetected Diurnal Variability



Jasper Lewis, Code 612, NASA GSFC, Ellsworth Welton, Code 612, Andrea Molod, Code 610.1

The exchange of heat, momentum, and atmospheric constituents between the surface and the free atmosphere takes place in the planetary boundary layer (PBL). During the day, solar heating causes the boundary layer to grow through convective processes that mix aerosols and moisture throughout the PBL, i.e., development of a mixed layer. Accurate measurements of the PBL height are important for air quality monitoring, weather forecasting, and climate modeling. Data collected during 2001-2011 from the NASA Micropulse Lidar Network (MPLNET) have been used to provide a climatology of mixing layer heights at GSFC.

- A new MPLNET PBL height algorithm has been developed which reveals previously undetected seasonal and diurnal trends.
- The new MPLNET mixing layer heights show reasonable agreement with GEOS-5, given the different criteria used to determine the PBL height.
- The correlation coefficient of monthly maximum daytime PBL heights for MPLNET and GEOS-5 increases from 0.51 to 0.72 using the new algorithm.
- Similar mixing layer height climatologies will be developed at other MPLNET sites around the globe and used to evaluate PBL retrievals from atmospheric models and CALIPSO.

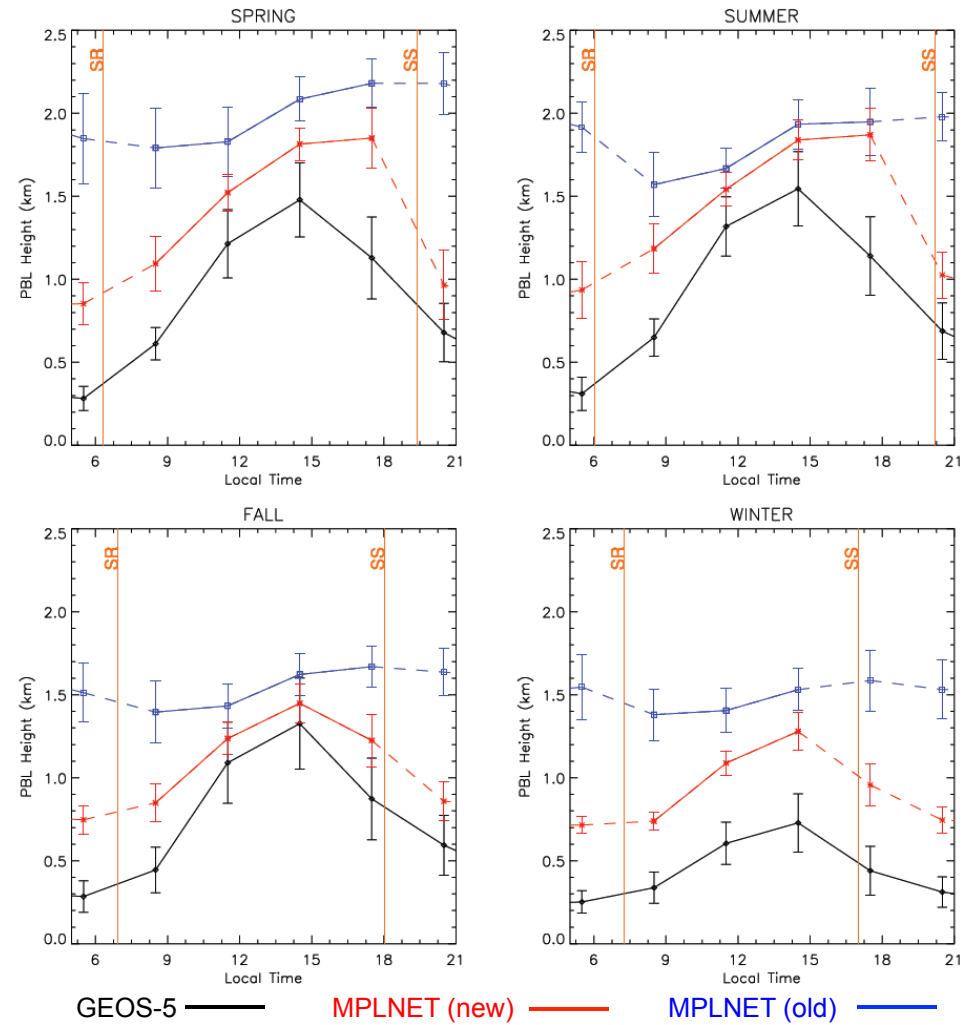
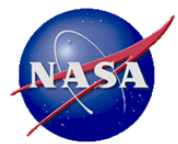
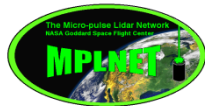


Figure 1: Comparison of seasonal diurnal cycles of the PBL height at GSFC for 2001-2008 using the new MPLNET algorithm (red), old MPLNET algorithm (blue), and GEOS-5 model (black). Orange vertical lines indicate the mean times for sunrise (SR) and sunset (SS). Daytime (nighttime) retrievals from MPLNET are symbolized using solid (dashed) lines.



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Lewis, J.R., E.J. Welton, and A.M. Molod (2012). Improved boundary layer heights from MPLNET in a local climatology, Submitted to *Journal of Geophysical Research*.

Molod, A., L. Takacs, M. Suarez, J. Bacmeister, I.-S. Song, and A. Eichmann (2012). The GEOS-5 Atmospheric General Circulation Model: Mean Climate and Development from MERRA to Fortuna. Technical Report Series on Global Modeling and Data Assimilation, Vol. 28.

We also credit the excellent work performed by the MPLNET staff.

Data Sources: NASA MPLNET, GEOS-5 AGCM

Technical Description of Figures:

Figure 1: Comparison of seasonal diurnal cycles of the PBL height at GSFC for 2001-2008 using the new MPLNET algorithm (red), old MPLNET algorithm (blue), and GEOS-5 model (black). Orange vertical lines indicate the mean times for sunrise (SR) and sunset (SS). Daytime (nighttime) retrievals from MPLNET are symbolized using solid (dashed) lines. An improved boundary layer height algorithm has been developed for the NASA MPLNET which reveals seasonal and diurnal trends undetected by the previous method of PBL height retrieval. As a result, it is now possible to perform comparisons and validation of atmospheric climate models (e.g. GEOS-5). In the figure, the MPLNET PBL heights have been averaged to the three-hour temporal resolution of the model for all years when data was available from both MPLNET and GEOS-5 (2001-2008). The new MPLNET PBL height algorithm shows more diurnal variation than the previous PBL height algorithm. The best agreement between MPLNET (new) and GEOS-5 occurs during the fall and the worst agreement occurs in the winter. Both MPLNET and GEOS-5 indicate the maximum PBL heights occur during the spring and summer seasons. However, the lidar-derived spring/summer PBL heights remain elevated late into afternoon while it collapses sooner in the model. The disagreement can be attributed to the difference in criteria used to define the PBL height (turbulence in the case of GEOS-5 and aerosol gradients in the case of MPLNET). In all seasons, nighttime retrievals are much lower in the model than from MPLNET due to instrument limitations that make it impossible to measure the low PBL heights (< 500 m) that occur under stable atmospheric conditions. Therefore, MPLNET PBL heights are best suited for daytime retrievals in convective atmospheres which generate strong vertical mixing of aerosols.

Scientific significance: Despite its importance in air quality monitoring, weather forecasting, and climate modeling, there have been a limited number of long-term, continuous observations of the PBL height recorded in climatological literature. Most PBL studies have been performed with radiosondes which are typically available twice a day (0000 and 1200 UTC) or have been limited to specific locations and short durations. With multiple continuously running lidar sites located around the globe and a multiyear record of atmospheric profiles, the NASA MPLNET provides a valuable dataset for improving our understanding of the PBL.

Relevance for future science and relationship to Decadal Survey: Mixing layer height climatologies similar to the current effort will be performed at multiple NASA MPLNET sites located around the globe. The information gained can provide validation and improvement of atmospheric general circulation models and satellite retrievals of the PBL height. Because the depth of the PBL is directly affected by land-atmosphere interactions, it can be used as an indicator of the land-surface energy balance, soil moisture, air pollution dispersion, and carbon dioxide concentrations.



Multi-sensor evaluation of aerosol retrievals shows large errors due to multiple aerosol layers

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Atmospheric aerosols exert a considerable impact on air quality, the hydrological cycle, and climate, and represent the greatest uncertainty in climate research. Aerosols are routinely measured by such satellite sensors as MODIS, MISR, OMI, SeaWiFS, POLDER, and CALIOP. However, the discrepancies and differences existing between the sensors and their aerosol products prevent the utilization of these resources to their full potential. The Multi-sensor Aerosol Products Sampling System (MAPSS) was developed to bridge this gap. MAPSS consistently samples spaceborne aerosol products over global Aerosol Robotic Network (AERONET) ground-based locations and generates the relevant statistics. Since the AERONET data are carefully inspected and quality-assured, they provide a suitable reference for integrated characterization of the spaceborne aerosol products as illustrated in **Figure 1 (top)**, where the simultaneous comparison of aerosol optical depth (AOD) retrieval from multiple satellite sensors over Dakar (Senegal) against corresponding AERONET observations highlights intrinsic differences and trade-offs that exist between the aerosol products. At this location, for instance, the MISR and MODIS DT (Dark Target) products provide the most accurate aerosol retrievals. However, since the MODIS DB (Deep Blue), OMI, and POLDER L (land) products have higher frequency of observation, they might be more suitable for applications that do not require the precise measurements of aerosols.

By bringing together aerosol products from multiple sensors, it has also become possible to better understand the potential sources of errors and uncertainties in these products from a more objective perspective, by leveraging the synergy between their unique qualities. For instance, in **Figure 1 (bottom)**, aerosol layer heights from CALIOP lidar are used to evaluate how AOD retrievals from OMI and POLDER (ocean) differ from those of AERONET as a function of the number of aerosol layers over Dakar. Apparently, the largest retrieval errors tend to coincide with the presence of multiple aerosol layers, indicating the need for improvement in spaceborne retrievals of aerosols under such conditions. Therefore, MAPSS facilitates improved understanding of certain aerosol retrieval accuracy limiting factors that cannot all be assessed from a single or even a few satellite sensors.

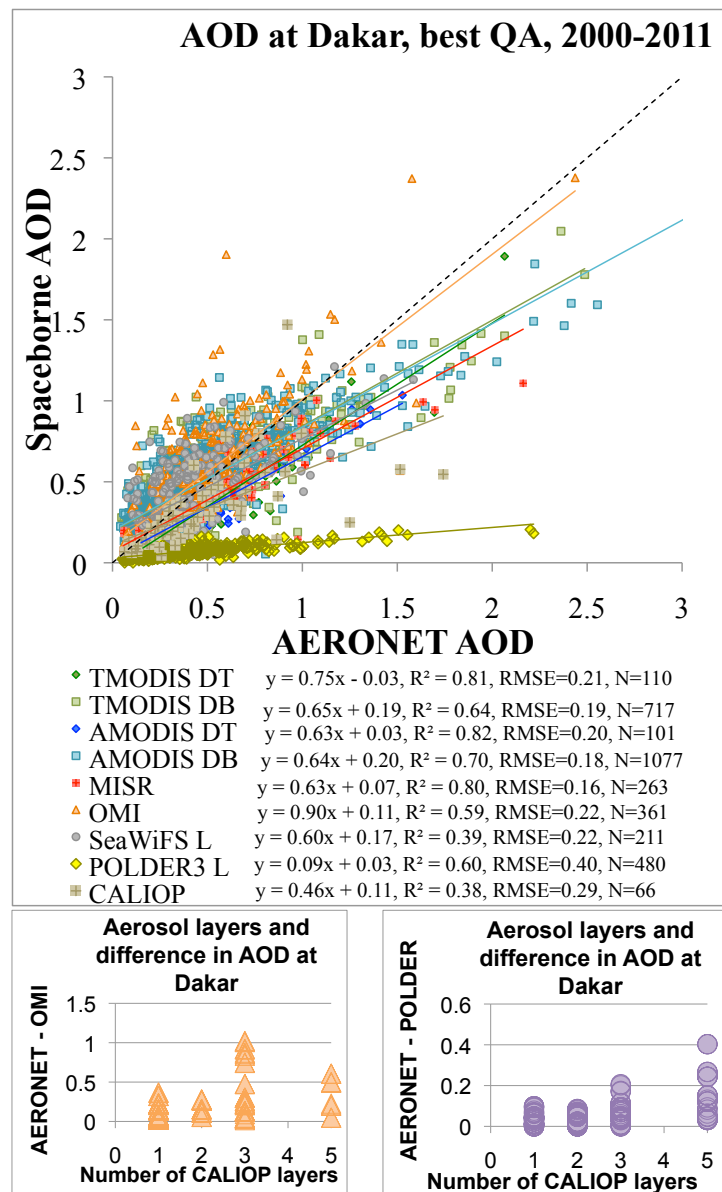


Figure 1: Multi-sensor aerosol analysis using MAPSS.



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References:

Petrenko, M., Ichoku, C., and Leptoukh, G.: Multi-sensor Aerosol Products Sampling System (MAPSS), Atmos. Meas. Tech., 5, 913-926, doi:10.5194/amt-5-913-2012, 2012.

Data Sources: Level-2 aerosol data from MODIS, MISR, OMI, SeaWiFS, POLDER, CALIOP spaceborne sensors and ground-base data from AERONET

Technical Description of Figures:

Figure 1 (top): . An example of simultaneous aerosol analysis from multiple sensors using MAPSS: multiple scatter plots showing their respective squared correlation coefficients (R^2) and root mean square errors (RMSE) between the means of AERONET aerosol optical depth (AOD) and the AOD of quality-screened aerosol products retrieved by the different spaceborne sensors in 2000–2011 over Dakar, Senegal. AOD is a first-order indicator of aerosol loading in the atmosphere from remote sensing.

Figure 1 (bottom): An example of aerosol analysis using MAPSS: differences (deltas) in means of AOD between ground-based and spaceborne observations in 2003-2010 over Dakar, plotted against the number of aerosol layers detected over this location. Data were screened using the following set of QA flags: OMI QA=0, POLDER (Ocean) Inversion QA>0.7. It can be observed that AOD differences between ground-based observations from AERONET and spaceborne observations from both POLDER (ocean) and OMI over Dakar are higher in the presence of multiple aerosol layers, based on layer retrievals from Calipso-CALIOP. In part, this difference can be explained by the possibility that multiple layers in a column can indicate multiple aerosol types and a multimodal size distribution, in contrast to the single aerosol layer monomodal models assumed in the retrieval algorithms of these instruments. Also, the high sensitivity of the OMI algorithm to aerosol layer height and the low sensitivity of the POLDER algorithm to non-polarizing particles might further contribute to the observed phenomenon. Please see Petrenko' 12 for the relevant references on the OMI and POLDER algorithms.

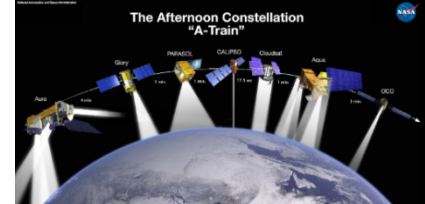
Scientific significance: MAPSS facilitates the investigation of various spatio-temporal properties of aerosols, as observed from multiple satellite sensors with complementary capabilities, thereby helping to expand our understanding of the distribution and environmental impacts of aerosols. Indeed, MAPSS-enabled availability of unified access to coincident aerosol parameters from multiple satellite sensors and AERONET provides a platform for gaining a more complete understanding of the interrelationships that may exist between the different aerosol physical properties that cannot all be measured from a single or even a few satellite sensors. Thus, MAPSS paves the way for a multitude of synergistic aerosol studies, some of which have probably not been considered till date.

Relevance for future science and relationship to Decadal Survey: Studies based on the MAPSS framework aim at identifying and quantifying uncertainties associated with aerosol retrievals from spaceborne sensors, with the goal of improving and eventually unifying these products in a coherent manner, thereby reducing the overall uncertainty associated with aerosol forcing calculations required for predicting future climate. The identified sources of uncertainties and their relative magnitudes will also inform the planning of upcoming missions of the Decadal Survey, such as ACE, by helping to better budget and mitigate or account for such uncertainties in the future aerosol products.



New fast simulator for cloud optical centroid pressure (OCP)

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 Pepijn Veefkind, Maarten Sneep, Johan de Haan (Royal Netherlands Meteorological Institute, KNMI)
 Igor Polonsky (Colorado State University) and Robert Spurr (RTSolutions)



The cloud optical centroid pressure (OCP) can be thought of as the mean pressure (inside a cloud) reached by solar light.

The OCP is needed for trace-gas retrievals (e.g., total column ozone, NO_2 , SO_2) that use reflected solar light.

The OCP is distinct from the cloud-top pressure (derived from thermal IR measurements); The two measurements are complementary and can be used to detect multi-layered clouds.

Our simulator transforms cloud optical extinction profiles into cloud OCP (as retrieved with the Aura Ozone Monitoring Instrument - OMI)

Full simulators for cloud OCP require expensive radiative transfer calculations (takes ~1 day for 1000 cloud profiles)

Our fast simulator does this in < 1sec

Fast simulators can be used for
 Evaluation of cloud outputs from GCMs
 Assimilation of cloud OCP retrievals
 Evaluation of cloud OCP retrievals

This study uses CloudSat and a full simulator for validation of OMI OCP retrievals and the fast simulator

Figure 1: Fast simulator “weighting functions” for a vertically uniform cloud shows how photons penetrate a cloud. As expected, in an optically thick clouds, most photons are backscattered from the upper part of the cloud, whereas sunlight reaches deeper into thin clouds.

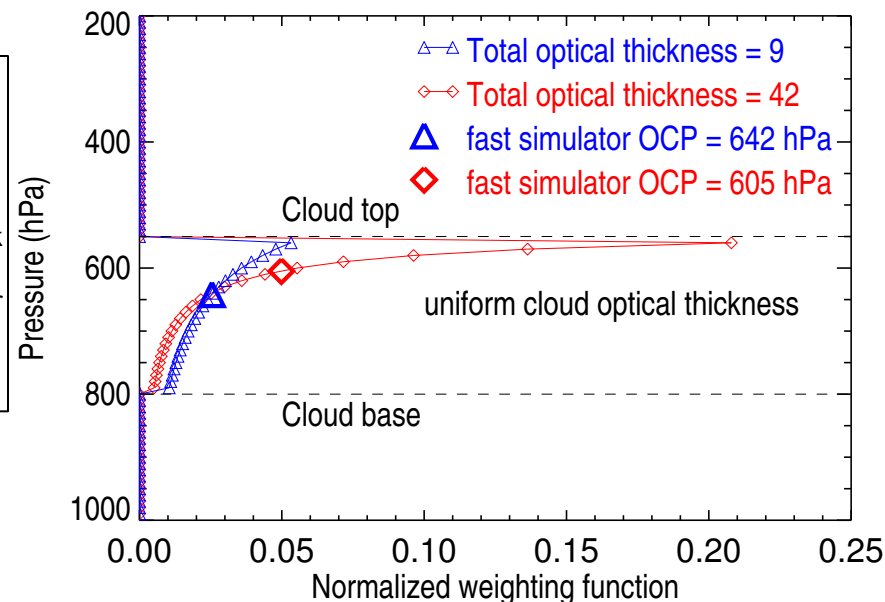
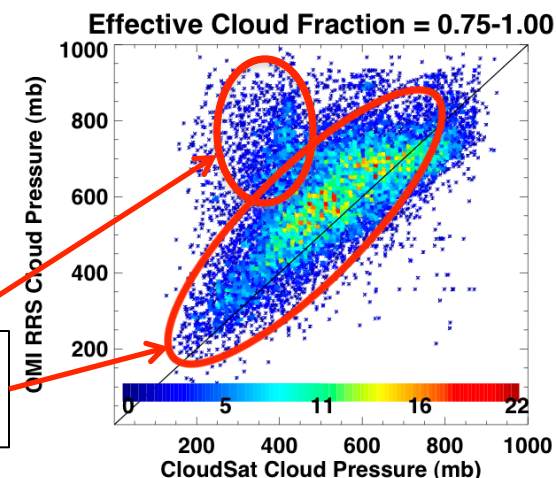


Figure 2: 2-D scatter diagram (histogram) showing a comparison between OMI cloud OCP retrievals and those expected from CloudSat/MODIS data. This comparison is enabled by the A-train and is the first of its type, providing the most thorough evaluation of cloud OCP retrievals to date.

Differences due to undetected snow/ice, aerosol, and low clouds not seen by CloudSat.

Overall good agreement with some differences attributed to fast model and OMI retrieval algorithm differences as well as collocation noise.





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References: Joiner, J., Vasilkov, A. P., Gupta, P., Bhartia, P. K., Veefkind, P., Sneep, M., de Haan, J., Polonsky, I., and Spurr, R., 2012: Fast simulators for satellite cloud optical centroid pressure retrievals; evaluation of OMI cloud retrievals, *Atmos. Meas. Tech.*, 5., 529-545, doi:10.5194/amt-5-529-2012.

Data Sources: Ozone Monitoring Instrument (OMI) Cloud Optical Centroid Pressure products from rotational-Raman scattering (OMCLDRR) and oxygen dimer absorption (OMCLDO2); CloudSat and MODIS combined cloud optical thickness profile (2B-TAU)

Technical Description of Figure: Our fast simulator produces an estimate of cloud OCP as well as a corresponding weighting function that shows the layer contributions to the cloud OCP. This figure shows how photons penetrate a hypothetical vertically uniform cloud. Also such clouds do not occur in nature, this example demonstrates clearly how solar photons penetrated inside optically thin and thick clouds and how the derived cloud OCP is not the cloud top pressure, but rather a reflectance weighted pressure inside the cloud. Cloud OCP retrievals are difficult to validate because before CloudSat, there did not exist global observations of cloud vertical profiles. The A-train provides a unique opportunity to evaluation cloud OCP pressures owing to the combination of MODIS radiances and CloudSat radar reflectivities that can be combined to produce an estimate of the cloud optical extinction profile. Figure 2 shows the most detailed evaluation of cloud OCPs to date. In this figure we compare cloud OCPs derived from OMI with near-coincident CloudSat/MODIS measurements run through the fast simulator. The figure shows generally good agreement with some differences that have been traced back to unidentified snow/ice, low cloud missed by CloudSat (as verified by CALIPSO also in the A-train), and biases in the fast simulator as well as in the retrievals.

Scientific significance: This study demonstrates that cloud OCPs derived independently from 2 different approaches both provide similar results and compare well with values predicted by CloudSat and MODIS. It provides further evidence that information on cloud vertical structure from MODIS thermal channels is complementary to that provided by solar backscatter measurements such as those from OMI. The information from OMI is needed to provide accurate trace gas measurements including retrievals of concentrations of pollutants and climate gases such as tropospheric ozone, NO₂, and SO₂. Cloud OCP information is also important for calculations of short-wave radiative fluxes and cloud forcing.

Relevance for future science and relationship to Decadal Survey: This work is relevant to all missions dedicated to the retrieval of trace-gases from solar backscattering including the decadal survey missions GEO-CAPE (tier 2) and GACM (tier 3). It is also relevant to the OMPS instrument on NPP and future JPSS instruments as well as to other similar international missions including the Korean GEMS and planned European geostationary satellites, the Global Ozone Monitoring Instrument 2 (GOME-2) on the EUMetSat MetOp series, and the European Space Agency sentinel 5 precursor TROPOMI.